Physics 10164 - Exam 3A

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

1. (30 pts) In the figure below, we are looking at a 3.5 cm x 3.5 cm square current loop the is oriented with its plane perpendicular to the axis of a 300 turn, 20 cm long solenoid. The 3.0 Ampere current in the solenoid is initially flowing in a clockwise direction. The square loop wire has a resistance of 0.075 Ohms.

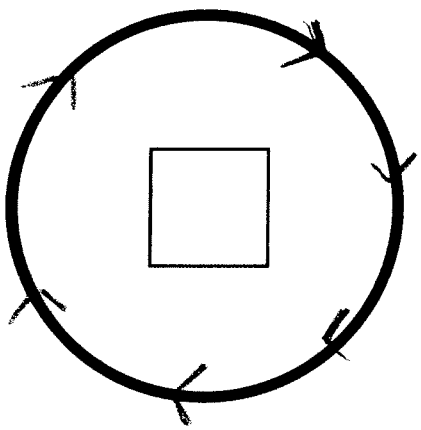
Now assume that the current in the solenoid drops to zero in a time interval of 0.11 seconds.

a) What is the initial direction of flux in the square loop? $\otimes$

b) How is the flux changing in the square loop? decreasing

c) In what direction is the induced magnetic field in the square loop? $\otimes$ to oppose change

d) What is the magnitude and direction of the induced current in the square loop during this 0.11 second time interval?



$B_{ind} = \otimes$

so I_{ind} is clockwise

$B_i = \mu_0 \frac{N}{L} I$

$= (1.26\times10^{-6})(\frac{300}{.20})(3.0) = .00567$

$B_f = 0$

$\Delta\Phi = B_i A - 0 = (.00567)(.035)^2 = 6.95\times10^{-6}\ T\cdot m^2$

$\mathcal{E}_{ind} = \frac{\Delta\Phi}{\Delta t} = \frac{6.95\times10^{-6}}{.11} = 6.3\times10^{-5}\ V$

$I_{ind} = \frac{6.3\times10^{-5}}{.075} = \boxed{8.4\times10^{-4}\ A}$

2. (30 pts) A circuit contains a DC power source with a voltage of 12 Volts, a 25 Ohm resistor and an inductor. When a switch is closed, connecting the voltage source to the rest of the circuit, an experimenter measures the voltage drop across the resistor to be 4.0 Volts after 0.15 seconds has passed.

a) What is the inductance of the inductor?

b) What is the voltage drop across the inductor at this time?

c) How fast is the current changing ($\Delta I/\Delta t$) at this time?

$$I = I_{max}(1 - e^{-t/\tau})$$

$$\frac{IR}{I_{max}R} = 1 - e^{-t/\tau}$$

$$0.33 = 1 - e^{-t/\tau}$$

$$-0.67 = -e^{-t/\tau}$$

$$\ln 0.67 = -\frac{t}{\tau}$$

$$\tau = -\frac{0.15}{\ln 0.67} = 0.375 = \frac{L}{R}$$

$$0.375 = \frac{L}{25}$$

$$\boxed{L = 9.4\ H}$$

b) If $\Delta V_R = 4.0\ V$, then $\boxed{\Delta V_L = 8.0\ V}$

(loop rule)

c) $\mathcal{E}_L = L\frac{\Delta I}{\Delta t}$ $\quad \frac{\Delta I}{\Delta t} = \frac{8.0}{9.4} = \boxed{0.85\ \frac{A}{s}}$

3. (40 pts) An RLC circuit contains a 120 Volt (rms) power source, a 4.0 Ohm resistor, a 75 μF capacitor and an inductor.

a) When operated at a frequency of 60 Hz, the circuit is found to be in resonance (rms current is maximized). What is the inductance of the inductor?

b) How much power is dissipated by the resistor when the circuit is running at this frequency?

c) How much power is dissipated by the resistor when the circuit is operated at a frequency of 30 Hz?

a) $f_0 = \frac{1}{2\pi\sqrt{LC}}$ $\quad L = \frac{1}{4\pi^2 f_0^2 C}$

$L = \frac{1}{4\pi^2(60)^2(75\times10^{-6})} = \boxed{.0938\ H}$

b) $I_{rms} = \frac{\mathcal{E}_{rms}}{Z} = \frac{\mathcal{E}_{rms}}{R}$ at resonance

$I_{rms} = \frac{120}{4.0} = 30\ A$

$P = I_{rms}^2 R = \boxed{3600\ W}$

c) $X_L = 2\pi f L = 17.7\ \Omega$

$X_C = \frac{1}{2\pi f C} = 70.7\ \Omega$

$Z = \sqrt{4.0^2 + 53^2} = 53\ \Omega$

$I_{rms} = \frac{120}{53} = 2.26\ A$

$P = I^2 R = \boxed{20\ W}$